Response to reviewers

Thanks for your great efforts and valuable comments, which helps to improve our manuscript. We have addressed the reviewers' comments on a point-to-point basis as below for consideration. Referee comments are in black. Author responses are in red. All the line numbers mentioned following are refer to the revised manuscript with no changes marked.

This manuscript is built on continuous aerosol measurements conducted during 4 springs in urban Beijing. The data and research topic are certainly of high interest. While the paper is well-organized and technically relatively well written, there are a few major issues that prevent me to recommend the publication of this paper in its present form. My main concerns in this regard are summarized below.

My first major comment is about the imbalance between the title of the paper and its contents. The title gives an impression that this paper is solely about association between new particle formation (NPF) and dust, but most of the results (sections 3.3-3.5 and a big fraction of section 3.2) have little/nothing to do with NPF. The same concerns the abstract.

Reply: Thanks for your helpful comments. In section 3.1-3.2, we generally described the dust days and NPF occurrence probability in spring from 2017 to 2021. The classification of two types of NPF events was conducted depending on whether the dust event occurred before NPF, to evaluate the influence of dust process on nucleation and growth process. In the section 3.3-3.5, we discussed almost the most severe dust storm case in recent twenty years and the following NPF case. For this case, we have relatively comprehensive measurements of particle size, chemical composition, hygroscopicity, which can help to reveal the variations of physical and chemical properties of nucleated particles, and even the ability to be activated as CCN. However, as reviewer mentioned, we should highlight the relationship with NPF in each section, to make the discussion more focused on how the dust particles modify the atmospheric conditions when NPF events occur.

One of the main results brought up by the authors is the contribution of anthropogenic emissions to particle formation and growth rates. Estimating such contributions is very difficult overall, and totally impossible when having no real-time measurements of low-volatile precursors causing NPF and growth. Simply comparing days with and without presence of dust cannot address this issue, so in this regard the conclusions made in this paper are not scientifically sound.

Reply: The influence of anthropogenic emissions on NPF event is difficult to be evaluated or quantified, especially in urban areas (Kulmala et al., 2022). In this work, we analyzed the long-term measurement of PNSD in spring in Beijing from 2017 to 2021, to characterize the NPF event influenced by dust process or not. However, as the reviewer mentioned, there is no sufficient percussor measurement, especially the low-volatile organic vapor. Thus, we revised the discussion and abstract, to address the influence of dust event on NPF, instead of accessing the contribution from anthropogenic emissions. For example, in the abstract, the description about "contribution of anthropogenic emissions" has been revised to "By comparing the two types of NPF events, the observed formation (J_3) and growth rate (*GR*) of dust-related NPF events were approximately 50% and 30% lower than the values of normal NPF days, respectively, due to the extremely low condensation sink (~0.005 s^{-1}) caused by the strong wind during the dust process. The difference of NPF parameters got smaller when nucleated particles grew into the sizes above 10 nm, as the anthropogenic emissions accumulated fast during the few hours when dust ended and favored the growth process in the later stage." We also revised the discussions and conclusions.

As noted by the authors, condensation sink (CS) is an essential parameter determining whether NPF is possible in various conditions. It is a pity that the authors did not calculate CS for course mode particle, as it would have been possible from APS measurements. The total CS was very likely dominated by dust particles at least during the heaviest dust storms, and this might be one explanation why NPF was observed after the storms rather than during them.

Reply: The authors totally agree with the reviewer's comment that the coarse mode particles are major sink for precursor gases, which can result in high condensation sink (*CS*). Thus, NPF events do not occur during dust period. When dust particles fade, the *CS* is quite low (~0.005 s^{-1}) due to strong dilution by wind, which favored for the NPF event occurrence. That means when we talk about NPF, the dust period has ended and the concentration of pre-existing particles is quite low, and thus the contribution of coarse mode particle to *CS* can be ignored. Unfortunately, the APS measurement was not continuous and only available on March 2021. We discussed a typical and most severe dust case during 2017-2021. For this case study, the APS data was available and the influence on *CS* is discussed. It was found *CS* during dust storm was <0.02 s^{-1}, whereas it was much lower than the value during air polluted conditions (~0.04 s^{-1}) before dust and decreased to be lower than 0.01 s^{-1} when NPF occurred, as shown in Fig. 8 in the manuscript. In this study, we focused on how the dust event modified the atmospheric conditions when NPF occurred.

There are potentially valuable data on non-NPF-related chemistry associated with dust/non-dust in sections 3.3-3.5. Unfortunately, the current discussion on these data is rather qualitative, relying mainly on finding reported by earlier literature, and providing little new scientific insight. For example, the statement on lines 304-305 is self-evident. The authors did not explain how they combined direct hygroscopicity measurements to the hygroscopicity estimated from measured aerosol chemical composition.

Reply: In this study, we provided valuable information about how the dust processes modify the atmospheric conditions which facilitate the NPF event, which has been rarely discussed in the open literature. However, due to the limited measurement data, some discussions are not thoroughly to give the scientific insight. We have supplemented discussions in the manuscript, to make the scientific conclusions more robust. For example, a profound discussion about how different dust types influenced NPF events was given and addressed the strength of dust processes determined the condensation sink before NPF event, which was a key parameter in determining the formation and growth rate of NPF.

The sentence of original line 304-305 has been removed. In this study, the hygroscopicity parameter (κ) is derived from H-TDMA directly, which was not estimated from chemical composition data from AMS. The variation of κ was consistent with the chemical component.

Minor issues:

lines 43-44: reduced compared to what?

Reply: the sentence has been corrected to "Model simulations were performed with and without dust, and the results predicted that total particle concentration and CCN were reduced by approximately 20% and 10%, respectively, as influenced by the dust pollution plume in East Asia (Manktelow et al., 2010)."

lines 54-55: 45% of aerosols. By what measure? AOD?

Reply: This sentence has been corrected to "However, based on the optical parameters, including particle linear depolarization ratio, volume linear depolarization ratio and lidar ratio derived from a Raman lidar, there were approximately 45% of aerosols below 1.8 km above the ground contributed by polluted dust (the mixture of anthropogenic aerosols and dust) in Northern China (Wang et al., 2021)."

line 305: this should be Fig. 10, not Fig. 8.

Reply: The hygroscopic parameters are given in Fig. 10, and the chemical composition are given in Fig. 8.

It is somewhat unclear what is the difference between positive and negative anomalies in Figure 3. Also, it not well explained what is subtracted from what in this figure.

Reply: We have supplemented the details of Fig. 3 in the text, to make it clear that how the anomalies are calculated. The anomaly plots were obtained by means of the PNSD of NPF occurring on non-dust days subtracting the mean PNSD of dust-related NPF in each spring from 2017 to 2021, and was shown in Fig. 3. The positive anomaly indicated how much the particle number concentration in each corresponding size bin on non-dust NPF days was higher than that on dust-related NPF days, whereas the negative anomaly indicated that PNSD was lower on non-dust NPF days.

Finally, it seems to me that not all references cited in the text can be found in the reference list.

Reply: The authors check through the manuscript and supplemented the missing references in the list.

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